HIGH-RESOLUTION MICROWAVE SPECTROSCOPY OF RADIOACTIVE MOLECULES: MASS-INDEPENDENT STUDIES OF AlO, TiO, AND FeO

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Astrophysical observations of radioactive isotopes, like ^{26}Al, ^{44}Ti, or ^{60}Fe, provide insight into the nucleosynthesis of stellar cores. The detection of characteristic γ-photons, which are released during radioactive decay, is used to map their spatial distribution on large scale. In general, the assignment to certain stellar objects fails due to limited sensitivity.
An alternative approach is the observation of molecules containing radioactive isotopes. Radio-telescope facilities, like *ALMA*, can identify these species via their rotational transitions. In the outer atmosphere of late-type stars, the molecular condensation starts with simple diatomic particles containing oxides of refractory elements. The astrophysical detection of diatomic radioactive molecules requires highly accurate rotational transition frequencies, which can be obtained from laboratory measurements of stable isotopologues using mass-independent Dunham parameters.
In this work, systematic studies are presented for ^{26}AlO, ^{44}TiO, and ^{60}FeO, as most promising tracers of nucleosynthesis in stellar environments, based on high-resolution measurements on the rotational transitions of their abundant stable isotopologues. Experiments were performed when a solid target (Al, Ti, Fe) is evaporated by a pulsed laser into an oxygen-rich buffer gas to form simple metal oxides. An adiabatically planar expansion of the gas into a vacuum chamber cools the gas to a few tens of Kelvin and subsequently, Doppler-free rotational absorption spectra are recorded in the frequency range up to 400 GHz. A global data analysis, which also includes results from the literature, reveals the molecular structure beyond the Born-Oppenheimer (BO) limit, resulting in experimentally derived BO correction coefficients of these species for the first time. Based on this analysis, the rotational transitions of the radioactive molecules are determined with high accuracy at the sub-MHz level, which enables their unambiguous identification in stellar environments.